Profitable and desirable corporate environmentalism in a delegation contract under incentive subsidy on abatement technologies

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This study investigates corporate environmentalism in a managerial delegation contract and shows that a well-designed subsidy scheme can enhance business profitability and thus, an environmental policy could lead to both social and private benefits. This analysis allows us to better understand the Porter's concept of environmental policy and firm's profitability.

Keywords: corporate environmentalism; environmental corporate social responsibility; managerial delegation contract; incentive subsidy scheme; Porter's hypothesis

JEL Classification: L13; L21; M14

1. Introduction

Since Porter (1991) and Porter and Van der Linde (1995) challenged the traditional view on the relationship between environmental regulation and competitiveness by suggesting that a well-designed regulation may enhance business profitability, there has been a growing interest in corporate environmentalism in recent business and economics literature.[1] However, most of the literature on the analysis of theoretical and empirical studies assumes a green-premium in prices, where firms' investments in emission abatement technologies lead to productivity gains.[2] In contrast, we construct a mechanism through which profits increase under the incentive subsidy on abatement technologies, which induces polluting firms' strategic concerns for environmental corporate social responsibility (ECSR) to be socially desirable. This allows us to investigate the Porter's concept of environmental policy and business profitability.

We consider two cases of corporate environmentalism in a managerial delegation model. In the process of ECSR, firms can reduce emissions by decreasing their outputs or by investing in abatement technologies (or both). We first consider the former case, in which each polluting

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[1] In the recent literature of instrumental environmental corporate social responsibility, Lambertini and Tampieri (2015), Liu *et al.* (2015), Hirose *et al.* (2017) and Lee and Park (2017) explained how ECSR is desirable for both firms and society. However, they emphasized the voluntary aspect of corporate environmentalism without considering the relationship between environmental regulation and industry competitiveness.

[2] See, for example, Ambec, et al. (2013) and the references therein.

firm decides its ECSR without abatement technologies, and a firm can reduce its emissions voluntarily by output reduction. In this case, we note a cost pass-through effect, under which a portion of the increased cost can be reflected in consumer prices, which is profitable to the firms. We also consider the latter case, in which each firm purchases abatement goods from the eco-industry under the incentive subsidy. We then show that a well-designed government subsidy on abatement technologies can induce polluting firms' strategic ECSR behaviors to be socially desirable. Hence, we conclude that welfare-improving alignment between private and social incentives is feasible, given an incentive subsidy scheme on voluntary self-regulation.

2. The Basic Model

We consider the following quasi linear utility function of the representative consumer, suggested by Singh and Vives (1984):

$$U(q_1, q_2) = A(q_1 + q_2) - \frac{(q_1{}^2 + 2\beta q_1 q_2 + q_2{}^2)}{2} \tag{1}$$

where $\beta \in (0,1)$ denotes the degree of product differentiation. The inverse demand function is linear:

$$P_i = A - q_i - \beta q_j,\ \ i = 1{,}2 \text{ and } i \neq j. \tag{2}$$

where P_i and q_i are firm i's price and quantity, respectively.

Both firms emit the same pollutants, but they can reduce their emission levels by purchasing abatement goods, a_i, produced in the eco-industry. We assume an end-of-pipe technology, in which an emission function is linear,[3]

$$e_i(q_i, a_i) = q_i - a_i \tag{3}$$

We also assume that the damage function is quadratic:

$$D = d(\sum_{i=1}^{2} e_i(q_i, a_i))^2 \tag{4}$$

where d (> 0) is the coefficient of the environmental damage function.

We consider a managerial delegation model,[4] in which each firm consists of an owner who

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[3] The reduction in gross emissions simplifies the analytical treatment because there is no interaction term between the outputs and the abatement goods. For a justification of this type of technology, see David and Sinclair-Desgagne (2005), Poyago-Theotoky (2007) , Canton *et al.* (2008), and Lee and Park (2011, 2017).

[4] Fershtman (1985) and Sklivas (1987) provided seminal papers on the managerial delegation game. Later, Lee and Park (2017) and Poyago-Theotoky and Yong (2017) applied this game to corporate

owns the firm and a manager who makes decisions based on the incentive contract designed by the corresponding firm owner. In particular, following Lee and Park (2017) and Hirose *et al*. (2017), the pay-off function of the manager of the polluting firm is:

$$T_i = \pi_i - \theta_i d(q_i - a_i)^2 \quad (5)$$

where π_i is firm i's profit and θ_i (≥ 0) is the internal emission price on the damage it produced, which represents the degree of ECSR, as determined by the owner of firm i. Note that each manager's compensation structure is proportional to a linear combination of profit and the ECSR incentive.

Without loss of generality, we assume that each firm's marginal production cost is zero and the unit price of abatement goods in the eco-industry is given by r. Further, we assume that the firm can receive a subsidy from government when it engages in abatement technologies, that is, when the firm decides to purchase abatement goods from eco-firms ($a_i > 0$). Here, we assume that the subsidy is nonlinear and is a function of both firms' degrees of ECSR, $S_i = S_i(\theta_i, \theta_j)$. This implies that when the owner decides to adopt ECSR (i.e., when $\theta_i > 0$), she also decides whether to engage in abatement technologies at the management level, after observing the government's subsidy policy. Hence, the owner of firm i maximizes the following firm's profit[5]:

$$\pi_i = P_i q_i \text{ when it decides not to adopt abatement technologies } (a_i = 0) \quad (6)$$

$$\pi_i = P_i q_i - r a_i + S_i(\theta_i, \theta_j) \text{ when it decides to adopt abatement technologies } (a_i > 0) \quad (7)$$

In the eco-industry, we consider a Cournot oligopoly where $m (\geq 1)$ eco-firms compete in producing abatement goods. The profit function of each eco-firm is:

$$\pi_e = r(a_E) a_e \quad (8)$$

where a_e is the individual production of each eco-firm and $a_E = \sum_{e=1}^{m} a_e$ is the total production of abatement goods. Following the market equilibrium approach in David (2005) and Canton *et al*. (2008), we assume that the market price of abatement goods is determined by the total demand of the polluting firms and the total supply of the eco-firms. That is, we have

environmentalism.

[5] Note that we also have $a_i = 0$ when $\theta_i = 0$ because purchasing abatement goods causes a cost without increasing revenue in the profit function in (6). Lemma 1 shows that the option of implementing no ECSR ($\theta_i = 0$) is not an equilibrium.

$a_E = \sum_{e=1}^{m} a_e = \sum_{i=1}^{2} a_i$ at market equilibrium.

The timing of the game is as follows: In the first stage, the government announces a subsidy plan for polluting firms, which engage in abatement technologies. In the second stage, after observing the subsidy plan, the owner of each polluting firm decides on a degree of ECSR and whether to adopt abatement technologies to maximize the firm's profit. The subsidy is only provided when the firm adopts abatement technologies, and is based on the degree of ECSR. If a subsidy is provided, then in the third stage, the eco-firm produces its abatement goods to maximize its own profit, expecting that the market price will be determined by total demand and total supply of the eco-industry. In the fourth stage, each polluting firm chooses its price and, if the owner decides to adopt abatement technologies, purchases abatement goods to maximize its own payoff function. All games are solved by backward induction.

3. The Analysis

3.1 Equilibrium without abatement goods ($a_i = 0$)

We first examine the equilibrium without abatement goods. If the owner of polluting firm decides to adopt ECSR without engaging in abatement technologies, then the manager of the firm maximizes the objective function in (6) with $a_i = 0$ in the fourth stage. Then, the first order conditions yield the following reaction functions:

$$P_i(P_j;\theta_i,\theta_j) = \frac{\left(A(1-\beta)+\beta P_j\right)\left(1-\beta^2+2d\theta_i\right)}{2(1-\beta^2+d\theta_i)} \tag{9}$$

This implies that the increase in ECSR can be carried over to increase in prices and thus, each firm has an incentive to adopt ECSR by restricting its output (i.e., there is an output-restriction effect).[6] Then, the equilibrium outcomes in the fourth stage are:

$$P_i^{O}(\theta_i,\theta_j) = \frac{A(1-\beta^2+2d\theta_i)(2-\beta-\beta^2+2d\theta_j)}{4-5\beta^2+\beta^4+2d(2-\beta^2)\theta_j+2d\theta_i(2-\beta^2+2d\theta_j)} \tag{10}$$

$$q_i^{O}(\theta_i,\theta_j) = \frac{A\left(2-\beta-\beta^2+2d\theta_j\right)}{4-5\beta^2+\beta^4+2d(2-\beta^2)\theta_j+2d\theta_i\left(2-\beta^2+2d\theta_j\right)} \tag{11}$$

$$\pi_i^{O}(\theta_i,\theta_j) = \frac{A^2\left(1-\beta^2+2d\theta_i\right)\left(2-\beta-\beta^2+2d\theta_j\right)^2}{\left(4-5\beta^2+\beta^4+2d(2-\beta^2)\theta_j+2d\theta_i\left(2-\beta^2+2d\theta_j\right)\right)^2} \tag{12}$$

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[6] Firms can reduce emissions by investing in abatement technologies or by decreasing their output (or both). The latter case of the output-restriction effect of ECSR is pointed out by Lee and Park (2017) and Hirose *et al*. (2017).

In the second stage, the first order conditions for maximizing profit in (12) with respect to the degree of ECSR yield the following reaction functions:[7]

$$\theta_i(\theta_j) = \frac{\beta^2(1-\beta^2+2d\theta_j)}{2d(2-\beta^2+2d\theta_j)} \tag{13}$$

This implies that the choices of ECSR are strategic complements and thus, there exists a cost pass-through effect, under which a portion of the increased cost can be reflected in consumer prices. That is, the firm can increase the equilibrium prices when it increases its ECSR because its rival firm also increases its own ECSR.

Finally, we have the equilibrium outcomes without abatement goods as follows:

$$\theta_i{}^O = \frac{\sqrt{1-\beta^2}-(1-\beta^2)}{2d},\ q_i{}^O = \frac{A}{1+\beta+\sqrt{1-\beta^2}}\ ,\ P_i{}^O = \frac{A\sqrt{1-\beta^2}}{1+\beta+\sqrt{1-\beta^2}}\ ,\ \pi_i{}^O = \frac{A^2\sqrt{1-\beta^2}}{(1+\beta+\sqrt{1-\beta^2})^2}\ ,$$

$$ED^O = \frac{4A^2d}{(1+\beta+\sqrt{1-\beta^2})^2} \text{ and } W^O = CS + \pi_1 + \pi_2 - \text{ED} = \frac{A^2\left(1-2d+\beta+2\sqrt{1-\beta^2}\right)}{\left(1+\beta+\sqrt{1-\beta^2}\right)^2}\ .$$

Lemma 1. *In the managerial delegation model, voluntary ECSR is always profitable even though it does not adopt abatement technologies.*

Proof. If the owner of polluting firm doesn't adopt ECSR, the objective function of the manager is the same with the profit in (6). Then, the equilibrium outcomes are: $P_i{}^N = \frac{A(1-\beta)}{2-\beta}$, $q_i{}^N = \frac{A}{(2-\beta)(1+\beta)}$ and $\pi_i{}^N = \frac{A^2(1-\beta)}{(2-\beta)^2(1+\beta)}$. Thus, $\pi_i{}^O > \pi_i{}^N$ for $\beta \in (0,1)$. Q.E.D.

3.2 Equilibrium with abatement goods ($a_i > 0$).

If the owner of the polluting firm decides to adopt both ECSR and abatement technologies, the firm can receive the subsidy from the government and thus, its profit function is given as in (7). In what follows, we construct an incentive subsidy scheme to induce polluting firms to engage in abatement technologies. We then show that an incentive subsidy scheme can induce polluting firms' strategic ECSR behaviors to be socially desirable.

Each firm is free to choose whether to engage in abatement technologies, and decides to do so if and only if this will lead to a higher profit than under no abatement goods, given the degree of ECSR. That is, when the owner of a firm decides whether to adopt abatement technologies in the second stage, the following inequality is a sufficient incentive compatibility condition for

[7] The third stage of choosing market equilibrium prices is not relevant in this game of no abatement goods.

both firms to choose abatement technologies:

$$\pi_i(\theta_i;\theta_j) = P_i q_i - r a_i + S_i(\theta_i,\theta_j) \geq \pi_i{}^{O}(\theta_i,\theta_j) \tag{14}$$

or

$$S_i(\theta_i,\theta_j) \geq \pi_i{}^{O}(\theta_i,\theta_j) - P_i q_i + r a_i \tag{15}$$

The condition in (15) means that the regulator must set $S_i(\theta_i,\theta_j)$ sufficiently high to ensure that profit under the subsidy are larger than that without abatement goods. In fact, the condition in (15) is binding if we consider a small amount of a (positive) fixed subsidy in $S_i(\theta_i,\theta_j) + \varepsilon$. Then, the profit with abatement goods in (14) under the incentive subsidy scheme becomes the same profit without abatement goods in (12), i.e., $\pi_i(\theta_i;\theta_j) = \pi_i{}^{O}(\theta_i,\theta_j)$. This implies that the same degree of ECSR without abatement goods in (13) can ensure that both firms engage in abatement technologies.

In the fourth stage, the manager maximizes its objective function in (5). Then, the first order conditions with respect to the price of the final goods and the amount of abatement goods yield the following equilibrium outcomes:

$$P_i{}^{*} = \frac{A(1-\beta)+r}{2-\beta} \tag{16}$$

$$a_i{}^{*} = \frac{2d(A-r)\theta_i - r(2+\beta-\beta^2)}{2d(2+\beta-\beta^2)\theta_i} \tag{17}$$

Note that $a_i{}^{*} > 0$ only when[8] $\theta_i > \frac{r(2-\beta)(1+\beta)}{2d(A-r)} \equiv \widehat{\theta_\iota}$.

In the third stage, the market clearing price is determined by the total demand and total supply, i.e., $a_E = \sum_{i=1}^{2} a_i = \sum_{e=1}^{m} a_e$. Then, the inverse demand function of the abatement goods is:

$$r(a_E) = \frac{4Ad\theta_1\theta_2}{(2+\beta-\beta^2)\theta_2+\theta_1(2+\beta-\beta^2+4d\theta_2)} - \frac{2d\theta_1\theta_2(2+\beta-\beta^2)}{(2+\beta-\beta^2)\theta_2+\theta_1(2+\beta-\beta^2+4d\theta_2)} a_E \tag{18}$$

This has a negative slope with total demand. Each eco-firm maximizes its profit with respect to its production of abatement goods, under the expectation of the market equilibrium condition, $a_E = \sum_{e=1}^{m} a_e = m a_e$. Then, we have the following equilibrium outcomes:

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[8] When $\theta_i = \theta_i{}^{O}$, we have $r = \frac{A(\sqrt{1-\beta^2}-(1-\beta^2))}{(m+1)(\sqrt{1-\beta^2}+1+\beta)} > 0$ and thus, $\widehat{\theta_\iota} = 0$. It implies that we have a positive amount of abatement goods in the equilibrium outcomes.

$$a_e{}^* = \frac{2A}{(1+m)(2+\beta-\beta^2)} \quad (19)$$

$$a_i{}^* = \frac{A(m-1)(2-\beta)(1+\beta)\theta_j + A\theta_i((1+m)(2-\beta)(1+\beta)+4dm\theta_j)}{(1+m)(2-\beta)(1+\beta)((2-\beta)(1+\beta)\theta_j+\theta_i((2-\beta)(1+\beta)+4d\theta_j))} \quad (20)$$

$$r^* = \frac{4Ad\theta_1\theta_2}{(1+m)((2+\beta-\beta^2)\theta_2+\theta_1(2+\beta-\beta^2+4d\theta_2))} \quad (21)$$

Then, we have the following equilibrium outcomes in the third stage:

$$P_i{}^* = \frac{A(1-\beta^2+2d\theta_i)(2-\beta-\beta^2+2d\theta_j)}{4-5\beta^2+\beta^4+2d(2-\beta^2)\theta_j+2d\theta_i(2-\beta^2+2d\theta_j)} \quad (22)$$

$$q_i{}^* = \frac{A\left(2-\beta-\beta^2+2d\theta_j\right)}{4-5\beta^2+\beta^4+2d(2-\beta^2)\theta_j+2d\theta_i\left(2-\beta^2+2d\theta_j\right)} \quad (23)$$

Using the condition in (15), we obtain the incentive subsidy, and the profit function of the owner of the firm becomes that given in (12). It yields that the same degree of ECSR, i.e.,

$$\theta_i{}^* = \theta_i{}^O = \frac{\sqrt{1-\beta^2}-(1-\beta^2)}{2d}.$$

Finally, we have the equilibrium outcomes for the subsidy on abatement technologies:

$$P_i{}^* = \frac{A((2-\beta)\sqrt{1-\beta^2}+m(1-\beta)(1+\beta+\sqrt{1-\beta^2}))}{(1+m)(2-\beta)(1+\beta+\sqrt{1-\beta^2})}, \quad q_i{}^* = \frac{A(2+\beta-\beta^2+m(1+\beta+\sqrt{1-\beta^2}))}{(1+m)(2-\beta)(1+\beta)(1+\beta+\sqrt{1-\beta^2})}$$

$$a_i{}^* = \frac{Am}{(1+m)(2+\beta-\beta^2)}, \quad r^* = \frac{A(\sqrt{1-\beta^2}-(1-\beta^2))}{(1+m)(1+\beta+\sqrt{1-\beta^2})},$$

$$\pi_i{}^* = \frac{A^2\sqrt{1-\beta^2}}{(1+\beta+\sqrt{1-\beta^2})^2}, \quad \pi_e{}^* = \frac{2A^2(\sqrt{1-\beta^2}-(1-\beta^2))}{(1+m)^2(2+\beta-\beta^2)(1+\beta+\sqrt{1-\beta^2})},$$

$$\text{ED}^* = d(Q-a_U)^2 = \frac{4A^2d}{(1+m)^2(1+\beta+\sqrt{1-\beta^2})^2} \quad \text{and}$$

$$W^* = \frac{A^2((2-\beta)^2(1+\beta+2\sqrt{1-\beta^2})+2m(2-\beta)(3-\beta^2+(3-\beta)\sqrt{1-\beta^2})-4d(2-\beta)^2+2m^2(3-2\beta)(1+\sqrt{1-\beta^2}))}{(1+m)^2(2-\beta)^2(1+\beta+\sqrt{1-\beta^2})^2}$$

Proposition 1. *In the managerial delegation model with a government subsidy, voluntary ECSR reduces environmental damage, but increases the consumer surplus and total social welfare.*

Proof. From the comparisons, we have the following outcomes for $\beta \in (0,1)$ and $m \geq 1$:

$$q_i{}^* - q_i{}^O = \frac{Am(\sqrt{1-\beta^2}-(1-\beta^2))}{(1+m)(2-\beta)(1+\beta)(1+\beta+\sqrt{1-\beta^2})} > 0, \quad a_i{}^* - a_i{}^O = \frac{Am}{(1+m)(2+\beta-\beta^2)} > 0 \quad \text{and}$$

${e_i}^* - {e_i}^O = \frac{-Am}{(1+m)(1+\beta+\sqrt{1-\beta^2})} < 0$. It implies that $\mathrm{ED}^O - \mathrm{ED}^* = \frac{4A^2dm(2+m)}{(1+m)^2(1+\beta+\sqrt{1-\beta^2})^2} > 0$ and

$\mathrm{CS}^* - \mathrm{CS}^O = \frac{A^2m\beta^2(2(2-\beta)\sqrt{1-\beta^2}+m(1-\beta+\sqrt{1-\beta^2}(3-\beta)))}{(1+m)^2(2-\beta)^2(1+\sqrt{1-\beta^2})(1+\beta+\sqrt{1-\beta^2})^2} > 0$. Therefore, we have

$$W^* - W^O = \frac{A^2m\left(4d(2+m)(2-\beta)^2+(1-\beta)\left(2(2-\beta)\left(1-\sqrt{1-\beta^2}\right)+m\left(2+\beta^2-2\sqrt{1-\beta^2}-2\beta\left(1-\sqrt{1-\beta^2}\right)\right)\right)\right)}{(1+m)^2(2-\beta)^2\left(1+\beta+\sqrt{1-\beta^2}\right)^2} > 0.$$

Q.E.D.

Proposition 1 states that subsidy-induced abatement technologies can produce more final goods, which yields a larger consumer surplus, and can reduce emissions, which yields less environmental damage. Hence, a welfare-improving alignment between private and social incentives is feasible, given an incentive subsidy scheme on voluntary self-regulation.

4. Concluding Remarks

We investigated Porter's hypothesis in a managerial delegation contract and showed that a well-designed subsidy scheme can enhance business profitability and thus, an environmental policy could lead to both social and private benefits. We found that a cost pass-through effect can increase consumer prices and the profitability of firms under corporate environmentalism. This analysis allows us to better understand the Porter's trade-off between environmental policy and firm's profitability.

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